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GIS-based Analysis ofPrivate LandsExpansion using High-resolution Satellite Imageryin Ulaanbaatar, Mongolia

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Abstract. Sprawling areas called"*ger-areas*"in Ulaanbaatar have beenrapidly encroaching on peripheral areas due to land privatization after the enactment of a new land law in 2002. We chose *ger-areas*to the northwest of Ulaanbaatar as the study area and determined the trends and geographical characteristics of newly developed private landsduring two periods, 2000-06 and 2006-08,using high-resolution satellite imagery datasets and GIS technology.The rates of increase of private lands were 88.90% and 1.98% for these periods, respectively, and land near main roads and on flat terrainswas preferentially developed.

Keywords: urban sprawl, ger-area,high-resolution satellite imagery, Mongolia.

1. Introduction

Urbanization is a worldwide phenomenon (Sudhira et al.2004). Whileurbanization pattern has not been determinedacademically across different areas, it is essential to understand urban development to avoid environmental problems due to urban sprawl (Weber2003). Urban sprawl, excessive spatial growth of cities (Brueckner 2000), is caused by complex driving forces (social, economical, political, and physical ones),their interactions, and associated processes (Fang et al. 2005; Gimblett et al. 2001; Weber 2003).The pattern of urban sprawl should therefore be considered in each area in order to realize desirable landscape and manage the natural environment.

AlthoughMongolia has abundant natural lands and a traditional nomadic culture, its population is mainly concentrated in Ulaanbaatar, the capital of Mongolia, where it increased rapidly from 0.58 million in 1992 to over 1.0 million in 2008 due to migration (National Statistical Office of Mongolia).

The dramatic transition from central planning to a market-based economy in the 1990s led to a revision of the land law in 2002, which implemented in 2003 (Asian Development Bank 2003; Bruun&Odgaard 1996; Kevin 2003; Pomfret 2000). The revised land lawallowed the citizens of Mongolia toown land for the first time in Mongolian history.Each household could own land (up to 0.07 hain Ulaanbaatar) by registering the land with the government.The law also permitted renewable, inheritable, and tradable long-term possession (Asian Development Bank 2003; Nixson& Walters 2006;Smith 2007; Takiguchi 2009). As a result, land privatization has become prevalent, especially in the sprawling areas of Ulaanbaatar.

Some parts of theprivatized areasare called "*ger-areas*" because most of the immigrants build *gers* (traditionaland portable Mongolian residences) or block houses enclosed by *khashaas*(wooden fences),shown inFig. 1, and these areas account forabout 60% of Ulaanbaatar city's population (UN-Habitat 2010). Although it is easy for people to build *khashaas* on a land and acquireit, modern infrastructures,such as piped water, sanitation, proper roads,public transportation, and heating systems, have not beenimproved (Kamataet

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Fig. 1: *Ger-areas* in the sprawlingareas of Ulaanbaatar.

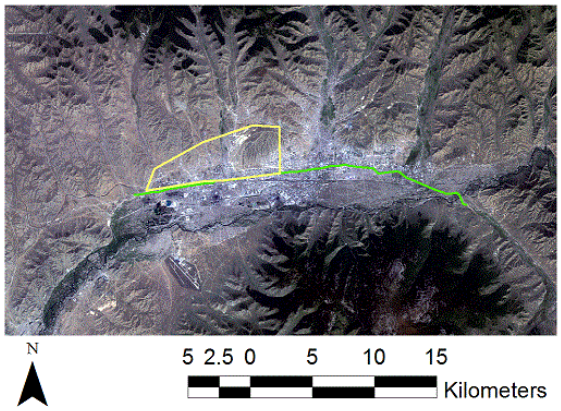

Fig. 2:Overview of Ulaanbaatar.Theyellow polygon and green line indicate the study area andEnkhtaivan Avenue, respectively (Landsat ETM, 31 Aug, 2001).

al. 2010).*Ger-areas* also have negative impacts on the human and natural environment due to unplanned and haphazard expansion (UN-Habitat 2010).It has been pointed out that social and spatial inequality, water supply and sanitation, waste management, flood risk reduction, and air pollution are challenging issuesin these areas (Kamataet al. 2010; UN-Habitat2010).Although a few microscaleapproaches for land use classification using high-resolution satellite imageryhave beenemployed (Amarsaikhan 2006;Amarsaikhan 2008;Amarsaikhan 2011), thereislimited previousresearch concerning the pattern of urban sprawl in Ulaanbaatar. The trend of private lands expansion was analysed and the geographical characteristics ofnewly developed private lands in *ger-areas*were focused upon to understand urban sprawl in Ulaanbaatar.

2. Materials and Methods

The study area is part of the districts of Songinokhairkhan and Bayangol,located in the western part of Ulaanbaatar between 106°43′E and 106°52′E, and 47°54′ N and 47°56′ N,and it has an area of about 33.26 km^2 (Fig. 2). One of the main roads,named EnkhtaivanAvenue,runs in the east–west direction in the southern part of the study area. *Ger-areas* are mainly distributedon the hillside on the northern side of Enkhtaivan Avenue. Onthe southern side of the road,there are many apartments and commercial facilities thathave better access to the central area of Ulaanbaatar.

We posit that Mongoliansgreatly prefer (1) placesnear main roadsfor easy access to the city center and (2) flat groundfor theconstructionofnew *ger*sor block houses.Thus, we identified the distance from main roads,which were paved andhad one or more lanes in 2000, and slopeasthe geographical factors for determining a location of a private land in the study area. We also calculated the area and number of private lands using GIS databasesthatwere obtained by digitizing aIKONOS image for 2000 andQuickbird images for 2006 and 2008.Only landsless than 0.1 ha in size were chosen for the calculation, considering the uncertaintyresulting fromthe digitization,thoughthe lawallowed people to own up to 0.07 ha.Main roads were also digitizedusing ArcGIS 10 and slope was calculated from ASTER GDEM data using ERDAS IMAGINE 2011.

The geographical characteristicsofthestudy area wereevaluatedon the basis of the*C*-value.The method of normalizing and weighting the indicators is often used for such evaluation (Haynes et al. 2008; Singh et al. 2009). The*C*-value at location*i*is defined by

$$C_i = \omega_1(r_i - \bar{r})/\sigma_r + \omega_2(s_i - \bar{s})/\sigma_s \quad (1)$$

Here, is the distance (m) from the main road to location*i*and is the slope (degree) at the location; and are the mean values of *r* and *s*, and are the standard deviations of *r* and *s*,and ω_1 anare

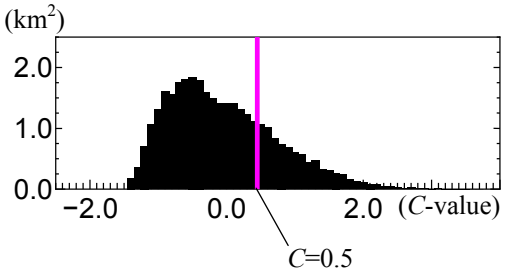

Fig. 3: Histogram of *C*-value.

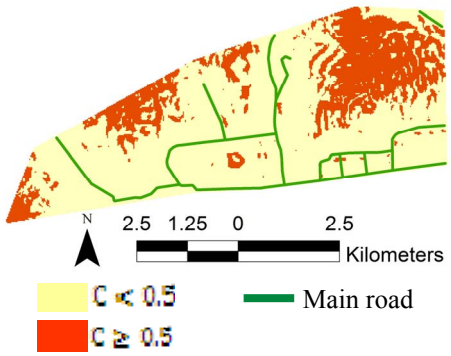

Fig. 4: Map of *C*-value distribution.

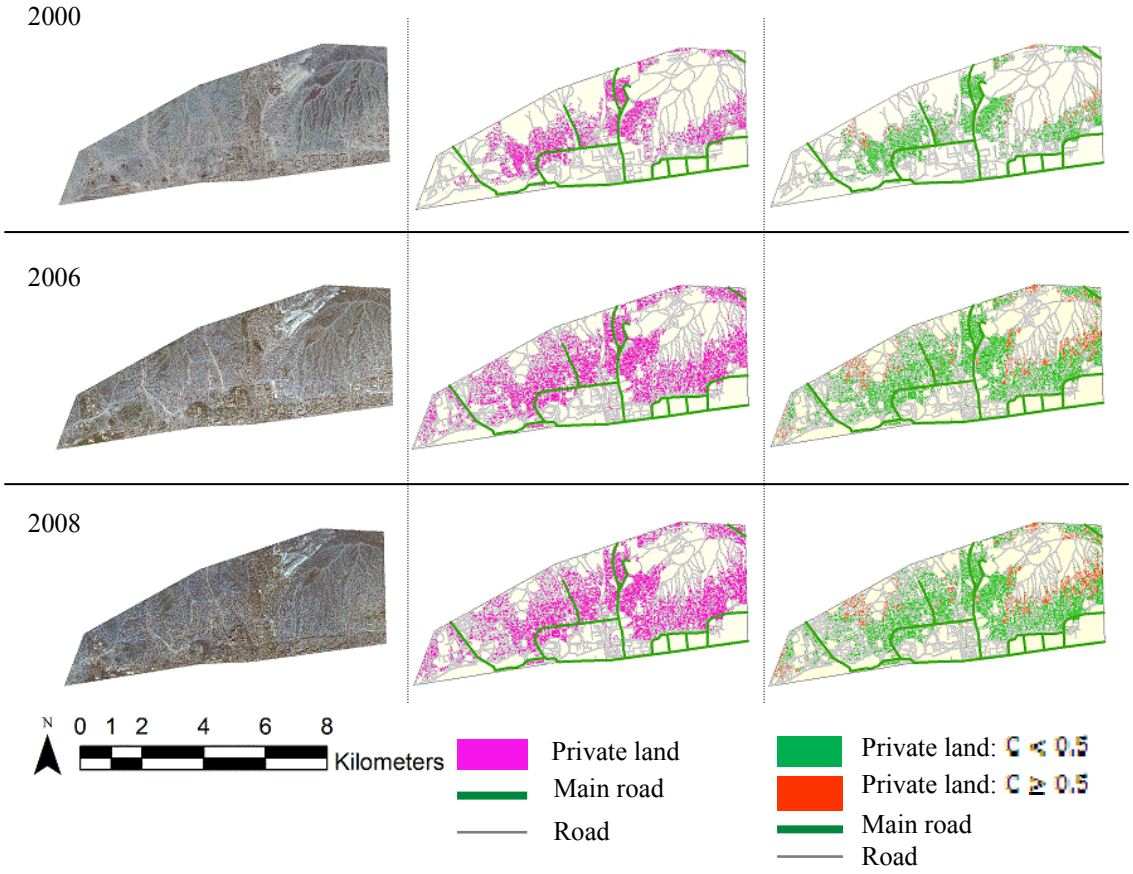

Fig. 5: Time-series analysis of private lands expansion in the study area. Satellite images of the study area (left), private lands, main roads,and road distributions derived from satellite images (middle), and distributions of private landsfor two different*C*-valueranges (right).

weighted values thatwere set as 0.5 in this evaluation. Each *C*-value at location*i*was calculated for a 26 m × 26 m cell.

It would be useful to decide a threshold value of C_i to express the geographical characteristics at location *i*, so we defined the threshold value as 0.5 for descriptive purposes. A histogram of the *C*-value and defined threshold value is shown in Fig. 3. Private lands located far from main roads would have low attractiveness for Mongolians, and steep slopes would be less suitable for the construction of new *gers* and block houses. Therefore, places with a lower *C*-value might be preferentially chosen for new development of private lands. We utilized the *C*-value to describe the spatial patterns of private lands in 2000, 2006, and 2008 and to detect the geographical characteristics of private lands.

Table 1.Number of and changes in private lands (2000, 2006, and 2008).

	Number in 2000	Number in 2006	Number in 2008	Changeover 2000–2006	Changeover 2006–2008
Private lands in the study area	5,264	9,944	10,141	4,680	197
(percentage of change)				(88.90)	(1.98)
Private landshaving $C < 0.5$	4,785	8,528	8,526	3,743	-2
(percentage of change)				(78.22)	(0.00)
Private landshaving $C \geq 0.5$	479	1,416	1,615	937	199
(percentage of change)				(195.62)	(14.05)

3. Results and Discussion

The results of the calculation and distribution of C-values are shown in Fig. 4. Locations having $C < 0.5$ are dominant in the study area, whereas those having $C \geq 0.5$ are found to be limited, being located near and on the top of hills. The proportion of locations having $C < 0.5$ and $C \geq 0.5$ in the study area is 75.06% and 24.94% .

We conducted an overlay analysis between the maps of *C*-values and private land distribution in 2000, 2006, and 2008. The results of the analysis are shown in Fig. 5 and summarized in Table 1. During the period 2000–2006, there was a sharp increase in the number of total private lands (from 5,264 to 9,944), and a rate of increase was 88.90%. In contrast, during 2006–2008, there was only a slight increase (from 9,944 to 10,141), and a rate of increase was 1.98%. No newly developed private lands having $C < 0.5$ were observed during the period 2006–2008, while the number of private lands having $C < 0.5$ increased rapidly (from 4,785 to 8,528) during the period 2000–2006 with a rate of increase of 78.22%. On the other hand, private lands having $C \geq 0.5$ still had a rate of increase of 14.05% in the period 2006–2008, after their dramatic increase from 479 to 1,416 in the period 2000–2006 with a rate of increase of 195.62%. Fig. 5 (right) also shows the trend of private lands expansion based on *C*-values. Private lands near the main roads and on flat terrain increased, and then places far from main roads and on steep slopes were developed. It is worth noting that all new developments of private lands between 2006 and 2008 were in places having $C \geq 0.5$. Most places having $C < 0.5$ had already been occupied before 2006, as shown in Fig. 5 (middle). It is expected that this trend will continue regardless that there are few chances to occupy at geographically advanced lands.

4. Conclusion

Spatial analysis using three high-resolution satellite images of 2000, 2006, and 2008 and geographic databases was conducted to understand the geographical characteristics of urban sprawl in Ulaanbaatar. The results clearly indicated that the revision of the land law greatly accelerated private landsexpansion in the sprawling areas. *Ger-areas*have continued to expandgradually since 2006. The study also showed that the expansion of private lands in *ger-areas*isassociated with the geographical factors of accessibility to thecity center and flat terrain.Private lands have been gradually encroaching on the hillsidethathasgeographical disadvantages and topographic risk compared to places developed before 2006. Appropriate urban planning and relevantregulationsare necessary to manage the urban sprawl.

5. Acknowledgements

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